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(54) Defrost control means

(57) A defrost control means for the evaporator of a refrigerator or heat pump has two active temperature sensors 9, 10, one of which is attached to the evaporator at approximately three-quarters distance along its length and the other is positioned in the path of air leaving the evaporator matrix. The difference in temperature between the two sensors is continuously compared with a reference level and a defrost cycle is initiated when the difference exceeds said level, that is in direct response to the increasing thermal insulation of the ice layer on the evaporator. The reference level is adjustable so that it may be preset according to the characteristics of a particular installation. Thus defrost is undertaken when required in direct response to the energy demand of the evaporator.

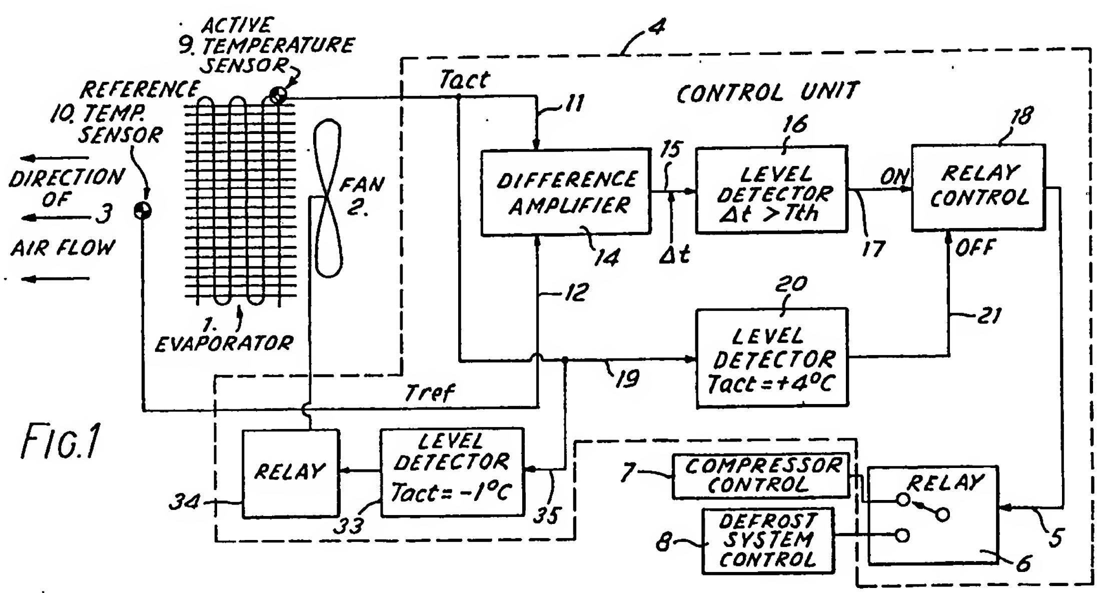

FIG.1

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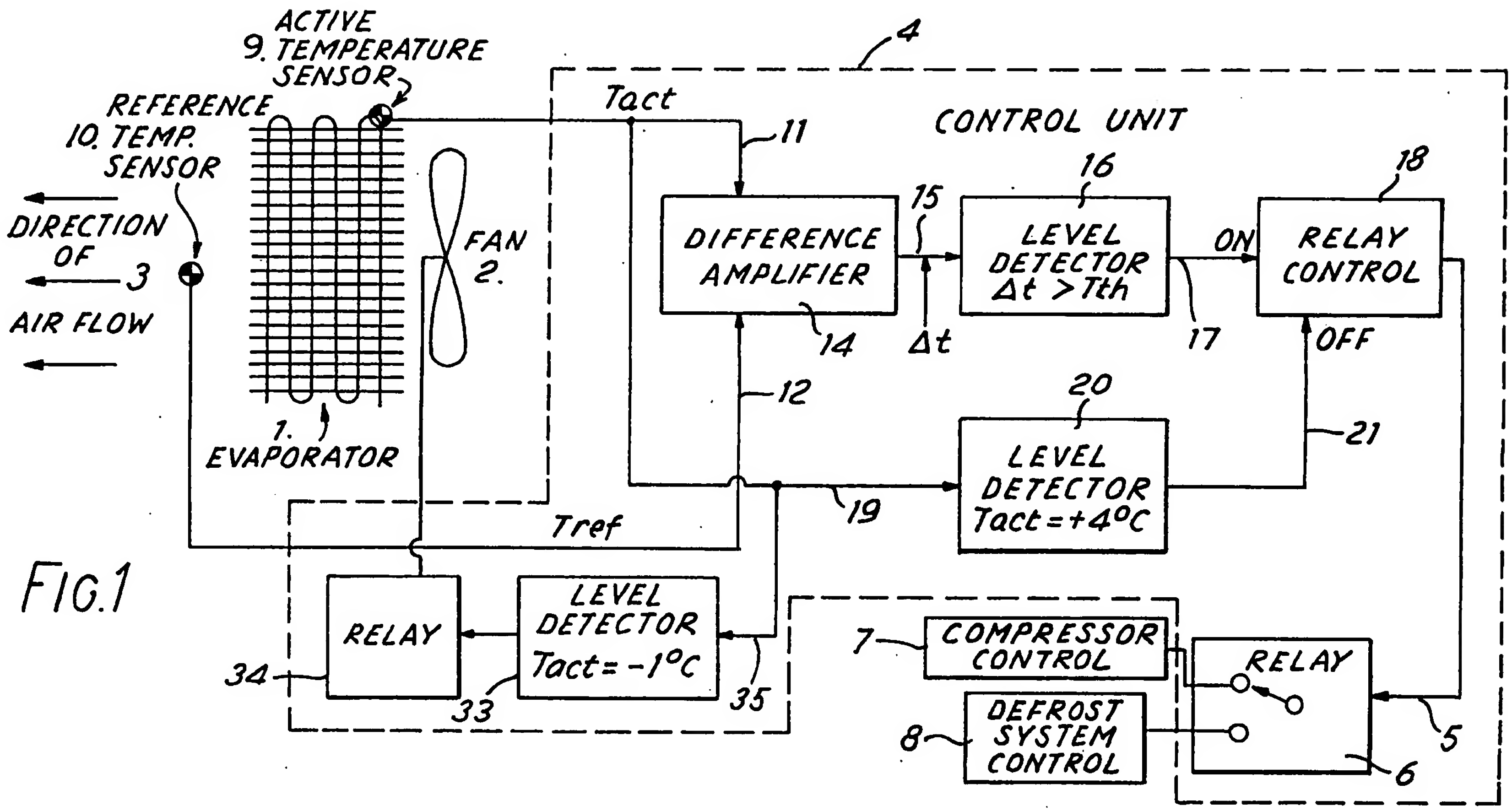

ACTIVE
9. TEMPERATURE
SENSOR
REFERENCE
10. TEMP.
SENSOR
DIRECTION
OF
3
AIR FLOW
1.
EVAPORATOR
FAN
2.
4
Tact
CONTROL UNIT
11
DIFFERENCE
AMPLIFIER
14
15
Δt
16
LEVEL
DETECTOR
Δt > Tth
17
ON
18
RELAY
CONTROL
OFF
12
20
LEVEL
DETECTOR
Tact = +4°C
21
19
Tref
RELAY
34
LEVEL
DETECTOR
Tact = -1°C
33
35
7
COMPRESSOR
CONTROL
8
DEFROST
SYSTEM
CONTROL
RELAY
5
6

FIG.1

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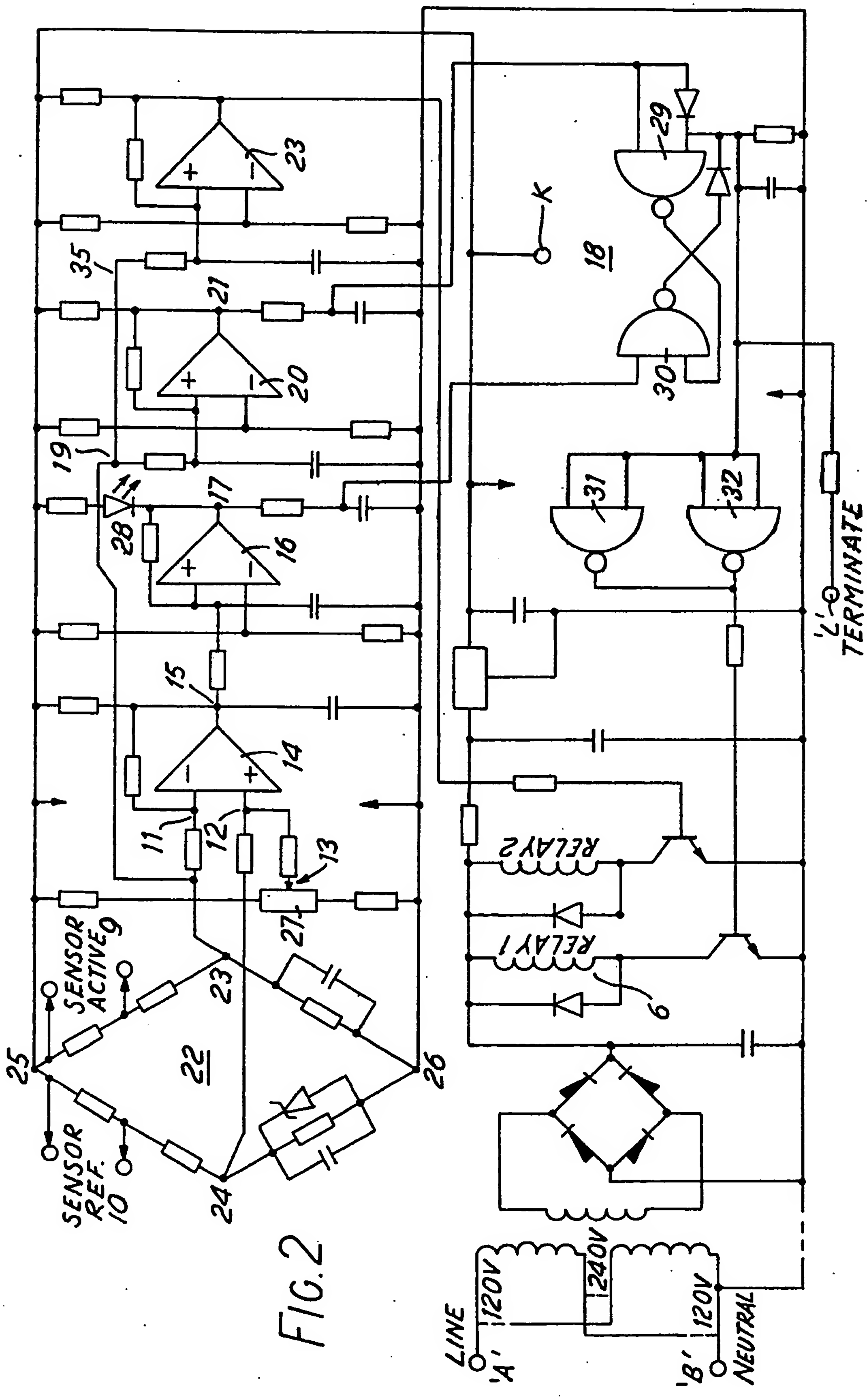

FIG. 2

SPECIFICATION
Defrost control means

The invention relates to defrost control means for the defrosting apparatus of a refrigerator or heat pump.

In refrigerators and heat pumps compressed coolant is allowed to expand into an evaporator during which process heat is absorbed from the evaporator surroundings.

Any humidity present in the atmosphere will form ice on the evaporator which, since ice is a poor thermal conductor, impairs the efficiency of the evaporator and the heat transfer capability of the system. Therefore it is necessary from time to time to remove such ice accretion by defrosting the evaporator: this may be done simply by manual control.

Previously proposed defrost controls have operated on a fixed time cycle in which defrost is carried out for a fixed time period at regular time intervals. This works well for only one set of prevailing ambient conditions and is therefore generally inefficient.

G.B. Patent Specification 1,404,210 describes a defrost on demand system for a particular installation in which an electric heater is energised for a period of time determined by a timer when the difference between the temperature of the evaporator coil and the air close to the evaporator exceeds a predetermined value. This arrangement is designed for one set of installation characteristics for which it may meet its efficiency objectives, but has the drawback that it is not easily adaptable to other installations possessing inherently different characteristics. For each individual installation it is necessary to redesign and recalibrate the components of the electrical circuit of the defrost control.

The present invention seeks to overcome these drawbacks by providing a control unit which is adjustable to suit a range of evaporator installations and characteristics.

According to the present invention there is provided a defrost control means for the defrosting apparatus of an evaporator of a refrigerator or heat pump comprising first temperature sensing means responsive to the temperature of the evaporator, second temperature sensing means responsive to the temperature of a fluid immediately after passing over the evaporator, means for deriving a quantity representing the temperature difference between the sensed temperatures comparator means having a first input connected to receive the quantity representing the sensed temperature difference and a second input connected to receive a selected comparator reference level and an output connected to indicate an evaporator defrosting cycle when the sensed temperature difference is greater than the reference level selectively adjustable over a range of values corresponding to any combination of evaporator characteristics and predetermined maximum level of evaporator insulation due to ice accretion.

The invention and how it may be carried into practice will now be described, by way of example only, with reference to the accompanying drawings in which:

Fig. 1 shows a block diagram of a defrost control means for a typical refrigerator installation, and

Fig. 2 shows a circuit diagram of the electronic defrost control of Fig. 1.

On a conventional evaporator, e.g. of the finned folded tube type, which is free of ice, the coldest point occurs approximately two thirds distance along the tube measured from the high pressure end (inlet) and the mean temperature of the evaporator settles at a value which gives maximum calorific absorption from air passing over the evaporator. As frost is deposited on the evaporator three separate but inter-related changes occur, firstly the refrigeration system attempts to maintain the same rate of calorific absorption and the mean temperature of the evaporator reduces, creating a temperature gradient across the ice layer. Second, the coldest point of the evaporator moves toward the low pressure end (outlet) of the tube, and third the difference between the temperature of air entering and leaving the evaporator fin matrix reduces.

Apparatus for carrying out the invention makes use of all three effects in order that the defrost initiation point can be selected with precision and stability. Two temperature sensors are employed, an "active" sensor which is affixed in good thermal contact with the evaporator coil about three-quarters distance along the tube from the inlet, and a "reference" sensor located in the air stream close to the evaporator.

Consider the operating conditions of an evaporator installation; let T_1 be the temperature of air entering the evaporator matrix T_2 be the temperature of exiting air, and T_3 the temperature of the evaporator itself. There is no calorific absorption in the matrix if

$$T_1=T_2$$

There is maximum heat transfer in the matrix if

$$T_1 \gg T_2$$

The defrost control is arranged to indicate a defrost cycle when:

a. $$T_1-T_2=T_x$$

where T_x is a constant dependent upon the installation.

Also there is maximum heat transfer when

$$T_2 \text{ approaches } T_3$$

and no heat transfer when/if

$$T_2 \gg T_3$$

and defrost occurs when

b. $$T_2 - T_3 = T_Y$$

where T_Y is a constant also dependent on the installation.

Ideally defrost should be initiated when both conditions a. and b. above are satisfied that is when:

If

$$T_x - K_1 = T_Y$$

where K_1 is a constant

$$T_1 - 2T_2 + T_3 - K_1 = 0$$

In the case of a cold store, substantially in equilibrium, T_1 is constant probably within the range minus 15°C. to ±1°C, which we can represent by another constant K_2.

Therefore

$$K_2 - 2T_2 + T_3 - K_1 = 0$$

Let $K_2 - K_1 = K$ where K is a constant dependent upon the installation and may be represented by an empirical quantity.

Hence

$$T_3 - (2T_2 + K) = 0$$

Referring now to the drawings, in Fig. 1 the evaporator of a refrigerator is generally indicated by reference 1 and at 2 a fan for circulating air in the direction of arrows 3 through the matrix of evaporator 1. A defrost control unit is generally indicated by the block reference 4 which provides an output 5 driving a relay 6 which controls energisation, generally in the alternative of a compressor 7 or a defrost system 8.

A first temperature sensing means, or active temperature sensor, 9 is attached in good thermal contact with the fabric of the evaporator 1, and a second temperature sensing means, reference temperature sensor 10 is positioned in the air stream adjacent, but not in thermal contact with, the evaporator 1.

The active and reference temperature sensors form part of an electrical bridge network, the output of which is fed through a buffer circuit to a voltage comparator which in turn controls initiation of a defrost cycle.

Defrost is initiated when the temperature difference between the sensors, that is the output of the bridge, reaches a preset value. This value is adjustable by means of a potentiometer which provides a pedestal or switching threshold voltage to the comparator input. This adjustment may be used to set the defrost control to suit any evaporator and any desired level of thermal insulation by ice accretion.

A defrost is terminated when the temperature of the active sensor reaches or exceeds a predetermined positive temperature, say 4°C.

The fan 2 is also driven from the same energy supply as compressor 7 but it is preferable to incorporate a delay in its control circuit 33 so that, following a defrost cycle, the fan is started after the compressor in order to allow any residual water drops on the evaporator matrix to be reconverted to ice.

In a heat pump installation used in conditions of high ambient temperatures, differences between the temperatures of the two sensors can be produced sufficient to induce defrost cycles even with an ice free evaporator. In order to prevent such unwanted defrosts the reference sensor is electronically clamped such that the voltage emerging from it can never represent a temperature higher than 0°C.

The temperature sensors 9 and 10 provide electrical signals, labelled T_{act} and T_{ref} in Fig. 1, connected to opposite inputs 11 and 12 respectively of an electronic differential amplifier 14. The output 15 of this amplifier which is proportional to the temperature difference Δt drives the input of a bi-stable or level detector circuit 16 which is arranged to change stage at voltage level proportional to a predetermined temperature difference. The output 17 of bi-stable 16 is arranged to occupy a first state when the temperature difference Δt is less than the predetermined level and to occupy a second state when it is greater than the predetermined level. The output 17 is connected to a relay driving circuit 8 which provides the output 5 to energise relay 6.

The signal from the temperature sensor 9 is also connected to:—

the input 19 of a second bi-stable circuit, or voltage level detector 20, which provides an output signal 21 connected to reset the relay drive circuit 18; and the

input 35 of a third bi-stable circuit, or voltage level detector, 33, which provides an output signal to control relay 34, and hence fan 2.

Referring now to Fig. 2 the temperature sensors 9 and 10 comprise thermistors, or other temperature sensors e.g. thermocouples, resistance thermometers, thermostats etc. connected in opposite arms of a resistive bridge circuit generally indicated at 22. One pair of nodal points 23, 24 of the bridge are connected respectively to differential amplifier inputs 11 and 12 whilst, the opposite pair of bridge nodal points 25, 26 are connected to a 12 Volts stabilised power supply.

The bridge 22 containing sensors 9 and 10 is connected to the inverting and non-inverting inputs 11, 12 of an integrated circuit comparator, configured as a differential amplifier, 14. The non-inverting input 12 of this "amplifier" is provided with a reference or pedestal voltage at 13 by means of a resistance chain including a variable potentiometer resistor 27 which may be adjusted to provide any selected amplifier zero level within a range of values.

The level detector bi-stable circuit 16 also consists of an integrated circuit comparator connected in nominal hysteresis circuit

configuration. An output switching level indicator in the form of a light emitting diode 28 is connected between the output 17 of this comparator and a voltage supply line. This is useful in initial setting-up of the circuit, in order to obtain the correct setting for potentiometer 27 by empirical means, when its setting is adjusted until the l.e.d. is just illuminated.

The relay control circuit 18 also comprises solid state circuits in the form of cross-coupled NAND gates 29, 30 and a pair of parallel NAND gates 31, 32 to supply the relay drive output to the first relay controlling a defrost heater.

The signal from active sensor 9 attached to the evaporator coil is also connected to two further comparators 20, 33 which provide respectively, a reset signal to the relay control circuit 18 and a second relay controlling fan energisation.

As previously mentioned the temperature sensor 9 is in thermal contact with the evaporator of the refrigerator system and the sensor 10 is positioned in the path of the air stream blown through the evaporator matrix by fan 2. Thus with no ice on the evaporator the refrigerator system will be operating at its highest efficiency so that to maintain a constant reference temperature, i.e. as sensed by the sensor 10, the evaporator will be at its least negative temperature. As ice begins to build up on the evaporator and act as a thermal insulator the energy input to the condenser via the compressor and compressor motor increases to maintain the desired outlet air temperature from the evaporator, thus reducing the evaporator temperature. At some point in this cycle it will become more economical to halt the refrigeration process and defrost the evaporator than it is to continue to operate the refrigerator system at an ever increasing work rate. At this point the bridge 22 reaches its present balance point as described above and causes the relay 6 to switch and change over the compressor 7 energisation to defrost system 8 energisation.

After the defrost system 8 has been in operation for a period of time the ice accretion on the evaporator 1 will have melted and the temperature of the evaporator will have risen to freezing or just above. The electrical signal from temperature sensor 9 which is monitoring the temperature of the evaporator 1 will be increasing during this time, and when it reaches the trip voltage level of bi-stable circuit 19 (in this example a temperature of +4°C) the output 21 changes state and resets the state of relay driving circuit 18. The relay 6 now de-energises and changes over again into its first state in which defrost system 8 is switched off and compressor 7 is actuated.

The defrost control means of the invention may be used with any of the defrost systems in present use. One of the most commonly used involves by-passing the condenser so that compressed refrigerant whilst still gaseous and hot is pumped into the evaporator which has the effect of reversing the heat flow in the evaporator. Another common arrangement is the reverse flow system in which the direction of flow of hot compressed gas through the condenser and evaporator is reverse; another is to employ a heating means in the vicinity of the evaporator e.g. an electric convection heater; and yet another system favoured for refrigerated holds in ships uses a water or brine spray onto the evaporator. The most commonly used method in domestic and other small refrigerators is merely to switch off the compressor and allow the temperature of the evaporator to rise to a temperature at which the ice accretion disperses naturally. This method is not suitable for commercial installations as it is too slow and allows the temperature of the contents of the refrigerator/freezer to rise to the same level as the melting point of ice.

It will be appreciated from the above that there are several variable quantities which may be selected to alter the operating characteristics of the system. For example the balance point of the bridge 22 containing the two temperature sensors may be adjusted to determine the amount of ice accretion tolerated before a defrost cycle is commenced and, the trigger voltage of the bi-stable 20 may be chosen to determine the point at which the defrost cycle is terminated.

In a refrigeration installation the reference temperature measured by sensor 10 is the temperature of the cold enclosure which, for example for a blast freezer or cold store, is normally minus 18°C to minus 30°C and the purpose of the system in operation is to maintain this temperature substantially constant. On the other hand, in a heat pump installation the reference temperature of sensor 10 is the ambient temperature of the surrounding and the temperature maintained by the system is that of the enclosure in which the condenser is located.

It would be possible to modify the above defrost control means to operate using an assumed temperature difference as an alternative to a temperature measured by two temperature sensors. In such a modification sensor 10 is dispensed with and sensor 9 is replaced by a thermostat set to operate at, say, minus 45°C and which is connected to trip the level detector 15 at that temperature to commence defrosting. The thermostat may also be connected to level detector 19 for the purpose of terminating defrosting when the evaporator has reached a sufficiently warm temperature. This arrangement, although less efficient might be employed where correct operation of the refrigeration system to maintain the cold store temperature is monitored by further means, not shown.

In the relay driving circuit 18 a pair of terminals L and K Fig. 2 are provided for the connection of a "fallback" thermostat (not shown) set to operate at, say, +6°C thereby to provide a fail safe mechanism in the event of malfunction of the defrost control means. Said thermostat is arranged to reset relay control 18 which action will terminate the energising current for relay 6 thus ensuring that the system does not stay in perpetual defrost.

Claims

1. Defrost control means for the defrosting apparatus of an evaporator of a refrigerator or heat pump comprising first temperature sensing means responsive to the temperature of the evaporator, second temperature sensing means responsive to the temperature of fluid immediately after passing over the evaporator, means for deriving a quantity representing the temperature, comparator means having a first input connected to receive the quantity representing the sensed temperature difference and a second input connected to receive a selected comparator reference level and an output connected to indicate an evaporator defrosting cycle when the sensed temperature difference is greater than the reference level, and means for providing said selected comparator reference level selectively adjustable over a range of values corresponding to any combination of evaporator characteristics and predetermined maximum level of evaporator insulation due to ice accretion.

2. Defrost control means according to Claim 1 comprising means for terminating the defrosting cycle when the temperature of the evaporator reaches a predetermined temperature.

3. Defrost control means according to Claim 1 or Claim 2 wherein the first temperature sensing means is arranged to be responsive to the temperature of the evaporator at a point approximately three-quarters distance along the length of the evaporator coil from the inlet end.

4. Defrost control means according to Claim 3 wherein said first temperature sensing means comprises a thermistor mounted in thermal contact with the evaporator coil.

5. Defrost control means according to any preceding claim wherein the temperature sensing means produce electrical signals, the means for comparing the sensed temperature difference with the predetermined threshold level comprises an electronic voltage comparator and said selected theshold level is determined by a voltage level at one input of the comparator.

6. Defrost control means according to Claim 5 wherein the threshold voltage level is produced by an adjustable potentiometer.

7. Defrost control means according to any proceeding claim including means providing an electronic limit on the reference sensor output corresponding to a predetermined temperature.

8. Defrost control means according to any preceding claim including means for controlling energisation of means of blowing air through an evaporator matrix and delay means responsive to re-energisation of a compressor at termination of a defrost cycle to delay re-energisation of said blowing means for a predetermined period.

9. Defrost control means substantially as hereinbefore described with reference to the accompanying drawings.

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